

**Gas Turbine Digital Engine Controller
Evaluation Criteria To Determine Technical Acceptability of Low Offer**

1. The Government intends to make a single award to the low price technically acceptable offeror. Technically acceptability shall be determined based on Technical Capability and Corporate Experience. In order to evaluate technical acceptability, offerors are required to submit information as part of their quotation addressing two factors, as discussed in Paragraph 1/2 below. A rating of Acceptable or Unacceptable shall be assigned under each of these factors, and on an overall basis. In order to be assigned an overall rating of Acceptable, an offeror must receive a rating of Acceptable in both Technical Capability and Corporate Experience. Failure to submit adequate information will result in a quotation being rated as Unacceptable. The Government intends on making an award based on the initial quotations received. Therefore, an offeror's initial quotation should contain its best offer from both a price and a technical standpoint.
2. The factors that will be used to assess technical acceptability are Technical Capability and Corporate Experience. As indicated above, offerors must furnish information as part of their quotations on these two factors as discussed below:

TECHNICAL CAPABILITY

In this factor offerors shall furnish information on its capability to furnish a multi-purpose engine controller for use in a Navy test cell that will meet all the requirements set forth in the Specification. This shall consist of information on the various processes and procedures that will be employed to produce the unit, such as material ordering, fabrication, production, assembly, and inspection or testing, that demonstrates the offeror understands and is capable of meeting both the technical requirements and the required delivery schedule.

CORPORATE EXPERIENCE

In this factor offerors shall furnish information on its overall resources and capabilities, such as facilities, equipment, management, personnel and quality system that demonstrates it possesses the ability to furnish the engine controller.



MILCON P-104 Gas Turbine Test Facility Performance Specification

Rev. B

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03/16/06	Initial	Baseline document	Joe Kingsley
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1. Referenced Documents

The following documents are in effect on the date of request for proposals.

- a) ISO9001 Quality System
- b) General Electric M50TF3832 (Latest Issue), Control System LM-2500 Commercial Marine Application
- c) General Electric M50TF3886 (Latest Issue), Electrical Interface Control Document

2. Introduction

2.1 Background

This specification provides the requirements for the manufacture, testing, and delivery of versatile, multi-purpose engine controller for use in a Navy test cell. This unit shall contain the control system hardware required to control and monitor the following General Electric stand alone gas turbines or Naval gas turbine packages: LM2500 (both hydro-mechanical and Digital Fuel Control (DFC)), the LM2500+, and the LM6000.

The Multi-Purpose Engine control unit shall be referred to as MPECU in this document. The MPECU shall be supplied with software to control both the hydro-mechanical and DFC configurations of the LM2500 naval package. Software to control and monitor the LM2500+ and LM6000 gas turbines will be required and developed at a later date under a separate contract.

A quantity of one (1) MPECU will be required.

2.2 Scope

This Performance Specification will describe the basic hardware requirements for the MPECU.

The requirements listed in this document are to be included as a minimum. Enhancements beyond the scope or deviations from the requirements of this document are at the discretion of the Gas Turbine Test Cell project manager. The Gas Turbine Test Cell project manager shall approve all deviations from this specification.



3. General Description and Definitions

3.1 Multi-Purpose Engine Control Unit (MPECU)

The MPECU shall provide the software and hardware to control and monitor the Gas Turbine parameters of a single LM2500 Gas Turbine Module (GTM), accommodating both the hydro-mechanical fuel control and DFC configurations, to operate over its rated performance range. In addition, the control system hardware shall be capable of controlling both the LM2500+ Gas turbine Module (GTM) and an LM6000 gas turbine to operate over their rated performance ranges. Software for control of the LM2500+ and the LM6000 is not included in this specification. The MPECU shall control all start/stop sequencing, to include normal and emergency stops of LM2500 GTM's equipped with either the DFC or hydro-mechanical fuel controls.

The loading of the application software to control the various LM gas turbines shall be accomplished via an application utility program. It is acceptable for additional software to be loaded in a similar method to configure the vibration monitoring system hardware for the various turbines.

The MPECU shall provide data logging functions as well as software based troubleshooting tools that will allow online monitoring of the graphical application program blocks as well as tools that provide the ability to change tunable parameters and view the logged data. The MPECU shall provide an interface with the government supplied Data Acquisition System (DAS) via a UDP Ethernet connection and shall provide a spare Ethernet port for future expansion.

3.2 MPECU Interfaces

MPECU shall electrically and physically interface with other equipment as defined in this document.

4. GTM Control Requirements

This section establishes the software technical and performance requirements for the MPECU for a GE LM2500 Marine Gas Turbine Module (GTM). The MPECU shall be provided as complete GTM control solutions, including all logic functions and associated software necessary to provide control and monitoring interface as required to operate the LM2500 GTM. The MPECU control and monitoring capability shall include GTM operation and a local graphical Human Machine Interface (HMI) utilizing Intellution iFix software.

4.1 Software Requirements

4.1.1 Programming language

The GTM control software shall be developed in a graphical, function block oriented programming language. The final program definitions shall also serve



as functional block diagrams. These diagrams shall be provided in addition to the source code, to the Government, for system documentation and troubleshooting information. A help file shall be provided which includes details on all program function blocks.

4.1.2 Compiled code

The final developed software shall be compiled into a machine language format to operate on a real-time operating system (RTOS) residing on the MPECU CPU card. This shall not be a Windows-based operating system. The final compiled product shall be a single Motorola Hexadecimal format (*.hex) file. This file shall be provided to the Government as a flash application for loading on the MPECU via a software management program, which allows the software to be downloaded to the control using an Ethernet connection.

4.1.3 Software configuration management

The contractor shall utilize a proven software quality program, which shall be applicable to all project software that is developed, maintained, or modified. Software development processes and quality program controls shall be in accordance with the contractor's standard commercial practices.

4.2 GTM Control Functionality

Performance requirements of the GTM control portion of the MPECU software are presented in the following paragraphs. All requirements of References B and C must be met in addition to those mentioned herein.

The GTM final control elements shall be operated by the MPECU software program and hardware. The MPECU shall provide all required manual controls, sequence logic, and interlocks to provide latching or momentary control signals as required by the GTM.

4.2.1 GTM Automatic Start Control

Automatic and manual GTM start control capabilities shall be provided. All pertinent operator controlled inputs shall be available on the local MPECU Human Machine Interface (HMI) panel.

4.2.1.1 Final Conditions

At the successful completion of either start sequence, the status of the control logic shall be set to the following:

- Start sequence logic reset to initial state
- Fuel valve open signal shall be maintained



- Ventilation dampers open signal shall be maintained
- Cooling fan shall remain running but start/stop commands shall be momentary

4.2.2 GTM Time Totalizing And Start Counter Meters

The MPECU shall be provided with a counter that advances the count by one each time the gas generator speed exceeds 4300 RPM and PT inlet gas temperature is greater than 400°F (which is the "engine running" indication) and fuel manifold pressure greater than 50 psig. The start counter shall be stored in non-volatile memory. The start counter shall be resettable through the MPECU HMI user interface.

The MPECU shall be provided with a time totalizing meter. The time totalizing meter value shall increment when the continuous signal in the above paragraph is true. The value of the meter shall be stored in non-volatile memory. The run time meter range shall have operational range of 0 to 32,000 hours in 1-hour increments. The run time meter value stored in non-volatile memory shall be resettable through the MPECU HMI user interface.

4.2.3 Throttle Input Command (TIC)

The MPECU HMI shall include a throttle interface, which can be used to incrementally increase gas generator speed. The MPECU throttle demand shall be based on a PLA position demand for a PLA fuel control system. The MPECU throttle demand shall be based on power turbine speed for a digital fuel control system. Other throttle control recommendations by the vendor will be considered but must be approved by the Gas Turbine Test Cell project manager.

The throttle input command shall be programmed so that the following conditions must be true in order to generate an above gas generator speed idle throttle command. Loss of any one of the below listed conditions shall result in a gas generator speed idle throttle command.

- Engine Running
- GTM Emergency Stop is inactive
- GTM Normal Stop Initiate is inactive

During GTM maintenance performance, such as PLA rigging, it is necessary to control TIC when the GTM is shutdown. The MPECU shall be programmed to provide a command via the local HMI to override the above listed permissives and connect the TIC to throttle.



4.2.4 Normal Stop Sequence

The MPECU shall be programmed to provide automatic stop controls to stop the GTM. Automatic normal stopping of the GTM shall be performed according to a prescheduled sequence.

4.2.5 Emergency Stop Sequence

The MPECU shall be programmed to provide automatic emergency GTM stop control to stop the GTM under emergency conditions when GTM safety is endangered (except for a fire condition). The MPECU shall also be able to accept a hardwired emergency stop input from a remote source. The remote source shall be a normally closed dry contact (contact opens for emergency stop). The fire stop sequence is specified in the following paragraph.

4.2.6 Fire Stop Sequence

The MPECU shall be programmed to provide an automatic shutdown sequence to stop the GTM in the event that a fire-extinguishing agent is released into the module. The MPECU shall be programmed to accept four dry contact closures for fire system monitoring (primary fire agent actuated, reserved fire agent actuated, primary fire agent released, and reserved fire agent released). The contacts are normally closed and open on activation of the fire agent. The fire shutdown shall be activated when either the primary actuated or reserved actuated contact opens. The MPECU shall send a stop command to the module cooling fan and close the vent damper when a fire shutdown is initiated. The MPECU shall also provide two +24 VDC commands to activate the fire agent system (Primary actuation and Reserve actuation). Manual operator initiated momentary commands shall be provided on the HMI. The command shall be held for a minimum of one second, and the circuit should provide a +24 VDC, 2.0A command to momentarily operate the fire agent discharge solenoid. The individual commands should be wire through contacts on the Fire Agent Release Inhibit switch located on the EOP which will open the circuit when the switch is in the inhibit position.

4.2.7 Stop Sequence Order Of Precedence

The three above mentioned stop sequences shall have an order of precedence whereby a stop sequence of higher priority will override a stop sequence that is in process. This descending order of precedence shall be:

- Fire Stop Sequence
- Emergency Stop Sequence
- Normal Stop Sequence



4.2.8 Hardwired Emergency Controls

The MPECU shall be programmed to provide the capability of the following operations by means of locally mounted hard-wired switches:

- GTM Emergency Stop (located on MPECU Emergency Operating Panel (EOP))
- Fire Agent Release Inhibit switch (MPECU Emergency Operating Panel (EOP))

The MPECU shall also be able to accept a hardwired emergency stop input from a remote source. The remote source shall be a normally closed dry contact (contact opens for emergency stop). Termination points inside the MPECU shall be provided for this hardwired emergency stop input.

4.2.9 GTM Control Functionality

The MPECU control and monitoring system shall provide interlocks and control sequencing signals to the GTM control elements. All pertinent signals shall be available on the Local HMI. The individual MPECU manual control functionality shall be as described in the following paragraphs.

4.2.9.1 Fuel Feed Control

The MPECU fuel feed control shall provide open and close signals to the main fuel valves during GTM start and stop sequences and shall maintain these valves in the open position while the GTM is running. The MPECU shall provide the following modes of main fuel valve control in accordance with References B and C:

- Automatic Control
- Manual Control
- Emergency Fuel Trip Valve Control

4.2.9.2 Power Turbine (PT) Speed Monitoring, Limiting and Overspeed Control

The MPECU shall provide PT speed monitoring, limiting and overspeed control with redundant monitoring circuits in accordance with References B and C. Signals from two PT tachometers shall be provided.

4.2.9.3 GTM Torque Monitoring and Limiting Control

The MPECU shall provide GTM torque monitoring and limiting control with calculated torque in accordance with References B and C.



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4.2.9.4 Gas Generator (GG) Speed Monitoring, Limiting and Overspeed Control

The MPECU shall provide GG speed monitoring, limiting and overspeed control with redundant monitoring circuits in accordance with References B and C. Signals from two GG tachometers shall be provided.

4.2.9.5 Starter Air Control

The MPECU shall provide starter air control to the GTM starter for all GTM start modes in accordance with References B and C.

4.2.9.6 Hydraulic start control

The MPECU shall provide hydraulic starter control for all GTM start modes in accordance with References B and C. The selection between pneumatic and hydraulic start should be software configurable.

4.2.9.7 Ignition Control

The MPECU shall provide ignition control to the GTM ignitor for all GTM start modes in accordance with References B and C.

4.2.9.8 Water Wash Control

Water wash system control is not required.

4.2.9.9 Bleed Air Valve Control

The MPECU shall provide manual bleed air control of the GTM bleed air valve for on the local HMI screen in accordance with References B and C.

4.2.9.10 Cooling Air Control

The MPECU shall provide automatic and manual modes of cooling air control to the GTM vent dampers and module-cooling fan for all GTM start modes in accordance with References B and C.

4.2.9.11 GTM Fire Monitoring and Control

The MPECU shall provide GTM fire monitoring and control in accordance with References B and C. A GTM fire alarm shall NOT automatically initiate a GTM fire stop sequence, but should provide an alarm indication to the operator on the local HMI alarm screen. The automatic fire stop sequence is described in section 4.2.6.

4.2.9.12 Lube Oil Monitoring

The MPECU shall monitor GTM lube oil supply and scavenge pressure in accordance with References B and C.



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4.2.9.13 Torque Monitoring

The MPECU shall continuously provide a computed GTM torque value in accordance with References B and C.

4.2.9.14 Inlet Gas Temperature Monitoring

The MPECU shall provide power turbine inlet gas temperature monitoring and control in accordance with References B and C.

4.2.9.15 Power Turbine (PT) Speed Monitoring

The MPECU shall continuously monitor redundant PT speed signals in accordance with References B and C.

4.2.9.16 Vibration Monitoring and Control

The MPECU shall continuously monitor turbine vibration with appropriate interface to the GTM control-sequencing program in accordance with References B and C. The vibration system shall be able to accept a velocity signal from the charge amplifiers mounted on the gas turbine module enclosure as well as acceleration inputs directly from the turbine accelerometers. The vibration input selection should be software selectable.

4.2.10 Battle Override Functionality

The MPECU shall provide a battle override function with interface to the control-sequencing program in accordance with References B and C. A battle override pushbutton shall be available to the operator on the local HMI screen.

4.2.11 Data Acquisition Interface

The MPECU shall provide an Ethernet port for communication with the data acquisition system (DAS) supplied by the government. The message to DAS shall be a UDP message at a rate of 10 Hz. The message shall include at a minimum the current status of all the analog inputs, digital inputs, analog outputs, digital outputs, alarms, shutdowns, and control regulator values. The vendor shall supply an interface definition document describing the message content and structure. Actual DAS message content shall be finalized between the government and the vendor upon contract award.

4.3 GTM Power Control Functionality

4.3.1 Throttle Control for PLA fuel system

The MPECU shall provide throttle control functionality on the local HMI control screen in order to adjust the power applied to the turbine. The MPECU throttle demand shall be based on a PLA position demand for a PLA fuel control system.



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Other throttle control recommendations by the vendor will be considered but must be approved by the Gas Turbine Test Cell project manager.

4.3.2 Throttle Control for Digital fuel control system

The MPECU shall provide throttle control functionality on the local HMI control screen in order to adjust the power applied to the turbine. The MPECU throttle demand shall be based on power turbine speed for a digital fuel control system. The MPECU shall be programmed to provide closed loop power turbine speed control using the demand signal set on the local HMI screen. Other throttle control recommendations by the vendor will be considered but must be approved by the Gas Turbine Test Cell project manager.



4.4 MPECU Maintenance Mode

The MPECU shall provide a maintenance mode of operation to perform specific types of GTM maintenance. The MPECU shall provide a maintenance mode selection on the local HMI screen. Maintenance mode shall provide the following:

- Output forcing of digital output commands

4.5 MPECU GTM Alignment Functionality

The MPECU shall provide an alignment mode of operation to perform specific types of GTM equipment alignments. The MPECU shall receive FMVA Alignment and VSV Alignment commands via the MPECU local HMI screen. These commands shall only be enabled if the GG speed is above 1220 RPM. The MPECU shall provide an indication on the local HMI screen that individual alignment modes have been entered.

4.6 MPECU Environmental Requirements

The MPECU equipment shall meet all requirements of the Referenced Documents and be capable of operation in a control room environment. The control system shall be capable of operating in an ambient temperature range of 0 to 50 degrees C., with up to 95% humidity (non-condensing).

4.7 Mounting Requirements

The MPECU shall be deck mounted. The Government assumes the responsibility for design and construction of deck assemblies for individual mounting of the MPECU. The Contractor shall submit to the Government any designs/drawings for mounting assemblies.

4.8 Color

The color of the MPECU enclosures shall be in accordance with the contractor's standard practices.

4.9 Cooling Requirements

The MPECU enclosures shall be air cooled as required, and shall derive their power off the facility 120 VAC supply or suitable internal power supply designed to withstand extended exposure to surrounding air temperatures within the range of 0 to 50 degrees Celsius. Cooling power shall be derived from the facility 120 VAC supply or suitable internal power supply.



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4.10 Maintenance

The MPECU enclosure configuration shall provide adequate access for normal maintenance of the enclosed components and peripherals. The enclosure shall be designed for front access only. A locking door is not required.

4.10.1 Operating Instructions and Safety Precaution Placard

Appropriate information plates showing safety precautions or operating instructions, which, if not observed, would result in material damage or personal injury, shall be provided. These plates shall have the word "WARNING" or "CAUTION" in double sized letters filled with red paint. The use of warning and caution plates shall be limited to the following conditions:

WARNING. Where nonobservance would result in personal injury or loss of life.

CAUTION. Where nonobservance would result in damage to, or destruction of, equipment or inadvertent shutdown of equipment.

4.11 Weight

The weight of the components shall be kept to a minimum, consistent with adequate design standards, and shall meet all environment and installation stresses with suitable safety margins.

4.12 Dimensions

The MPECU enclosure dimensions shall be as compact as reasonable but still allow easy internal access for parts removal, maintenance and cabling. Cabinet dimensions are limited to 10 feet in length, 3 feet in depth, and 6'2" tall (including any base pallet height).

4.13 Cable access

The MPECU shall include a removable gland plate on the bottom of the enclosure for cable access. The minimum dimensions of the gland plate should be 24" wide x 18" long.

4.14 Materials

Materials used in the construction of the components shall be of a grade suitable for the purpose intended. Prohibited materials are as follows:



PROHIBITED MATERIALS
Asbestos; asbestos compounds; and asbestos filled molding compounds.
Atmosphere contaminating solvents, inks
Cadmium
Carcinogens
Chlorofluorocarbons (CFC), i.e., Freon
Flammable materials
Fragile materials
Lithium and lithium compounds except CPU batteries
Magnesium or magnesium based alloys
Mercury or its compounds and amalgams
PVC insulation, except COTS items
Radioactive materials, e.g., Radium
Wood

4.15 Accessibility

The design of the enclosure shall be such that all wiring, terminals, and electrical connections shall be accessible for servicing and test purposes without requiring the removal of a part or subassembly from the enclosure in which it is mounted.

4.16 Maintainability

The equipment shall be designed so that it does not require scheduled maintenance except for cleaning and filter replacement.

4.17 Workmanship

Workmanship shall be in accordance with best commercial practices.

4.18 Interchangeability

All identically identified components shall be functionally and physically interchangeable without degradation of performance, reliability, or operating characteristics, and without selective assembly or modification, except for calibration and adjustment. Repair parts shall be interchangeable with, and identified identically to, the parts they replace.



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4.19 Safety

The components shall incorporate hardware and procedures reflecting consideration of recognizable hazards, potential hazards and the applicable safety measures so that injury to personnel and damage to the equipment will not result from failure of a unit installed in the components. Hazard definition shall be specified in MIL-STD-882. Safety features shall be incorporated into the components in the order specified for the system safety precedence as follows:

- a. Design for minimum hazard.
- b. Use of appropriate safety devices.
- c. Use of appropriate warning devices.
- d. Use of special procedures.

4.20 Human Performance/Human Engineering

The equipment interfacing with the operator shall be designed in accordance with the contractor's standard practices, and shall meet the intent of requirements of MIL-STD-1472F.

4.21 Miscellaneous Physical Requirements

4.21.1 Service and Access

The equipment shall be designed to provide accessibility to perform fault detection, preventive maintenance and component replacement.

4.21.2 Special tools

The requirements for using special tools shall be minimized. The Contractor shall provide special tools as required to perform all adjustments and to install and repair parts provided. Special tools are those not listed in the Federal Stock Supply catalog.

5. Electrical Requirements

5.1 Power Supply

The MPECU shall receive 120 Vac, 60 Hz, single phase, type 1 power per MIL-STD-1399. The vendor shall provide the government with the power dissipation requirements so the government can plan on providing adequate power for the MPECU.

5.2 Electrical Bonding

Connections of internal wires shall meet the intent of any applicable portions of MIL-STD-1310G.

5.3 Grounding

Grounding shall be in accordance with applicable portions of MIL-STD-1310. Primary power circuits shall not be directly grounded to the chassis structure.



Where capacitive type of grounding is necessary, such capacitance shall be as small as practicable.

5.4 Electrical Insulation

5.4.1 Insulation protection

Electrical insulation shall be in accordance with an appropriate MIL-W Wire Spec. Dielectric strength and insulation resistance

5.4.2 Dielectric strength and insulation resistance

Dielectric strength and insulation resistance clearances shall meet standard commercial requirements

5.5 Circuit Protection

The circuits required herein shall be designed to be isolated from each other for parallel circuits and from circuits of other systems to the extent that the shorting or opening of any portion of one circuit shall not produce cascading effects or a change in any other circuit in excess of the performance requirements specified herein.

5.5.1 AC Power

A guarded, main power circuit breaker shall be provided and mounted inside the cabinet. The breaker shall be labeled "Main AC Power". A Power On Lamp shall be supplied on the local control panel to provide the operator with an indication that this main circuit breaker is in the closed position.

Downstream of the main AC power circuit breaker, circuit breakers shall also be provided which secure power to the internal DC power supplies. The circuit breakers should be mounted inside the enclosure. The MPECU should monitor the output of the DC power supplies and provide the operator with an alarm on the local HMI screen when a power supply is off and/or failed.

5.6 Electromagnetic Radiation

Electromagnetic radiation requirements have been waived for this specification.

5.7 Miscellaneous Electrical Requirements

All internal MPECU enclosure cabling shall be installed in a secure fashion in accordance with commercial standards and shall not impede access to internal components. Terminal boards shall be of best industrial quality.



- Internal wiring shall be terminated on DIN-type terminal blocks mounted within the MPECU enclosure. Terminal blocks shall be UL approved, rated for 10-24 AWG wire, 600 V, 30A service.
- Terminal boards shall have appropriate spare terminals.
- Conductors shall be identified.

5.8 Protection of Parts

Circuit boards for critical control system hardware shall have conformal coating.

6. MPECU Internal Component Requirements

6.1 VME-Based Equipment Overview

The MPECU components shall provide the monitoring, control and display functions defined within this document. The hardware shall include the capability to monitor and control all I/O for an LM2500 GTM, an LM2500+ GTM as well as an LM6000 GTM. The hardware configuration should provide the ability to control turbines with both hydro-mechanical and digital fuel control. The hardware configuration should also provide the option for both pneumatic and hydraulic start capability of the turbines. The hardware configuration should provide the capability to accept either a velocity or acceleration input for vibration monitoring of the turbines. The system shall be capable of redundant CPU operation.

6.2 VME-Based Rack

The number of VME racks is not limited within this specification. The VME racks should include all the hardware necessary to monitor and control an LM2500 GTM, an LM2500+, and an LM6000. The hardware configuration should also take into account the ability to add additional I/O boards for future expansion.

The VME rack shall be composed of a chassis with a VME backplane inserted in the back of the rack assembly for connections between the fans, switches, power supplies, and VME cards. The cards shall use a VME-based bus standard for connector specification and data transfer. Slot-to-slot logic and power connections shall be made through the backplane. I/O connections shall be made through cables from the front of the boards to field termination modules (FTMs) in the MPECU enclosure.

6.3 CPU Section Components

6.3.1 CPU Card

The CPU shall be selected based on the vendor recommendation that would provide the best performance for this application. It is recommended that the CPU have the following: The CPU Card shall have two Ethernet ports capable of



interfacing to local PC for HMI and diagnostics display, and an RS-232 serial port. The application software shall be downloaded using one of the two Ethernet ports or the serial port. The RS-232 port (selectable baud rate from 300 baud to 38.4 Kbaud) shall be an alternate for software loading. The front panel shall include indicators for Fault, Run, I/O Lock, Low VCC and watchdog. The CPU card shall also be equipped with a reset switch. The CPU shall run diagnostics at power-up or at any time the Reset switch is toggled (off-line), and automatically when operating under application-program control (on-line). The CPU card, or an additional card in the chassis should provide an Ethernet port for communication with the Test Cell Data Acquisition System. An alternate Ethernet port should also be provide for future expansion. The CPU should be capable of running alone or in a master/hot backup arrangement in which the failure of the master CPU causes control of the system to transfer to the backup CPU in less than 1 ms with the loss of no more than one recursion rate. Control of the system can be transferred back to the original master CPU when it is again available. This transfer will occur in the same manner as the original transfer and in the same transition speed as the original transfer.

6.4 I/O Section Components

The I/O section of the MPECU shall house items identical or equivalent to items listed below (quantities dictated by final design). The I/O section receives control commands from the CPUs in the CPU section. The I/O section shall be located in VME chassis mounted within the MPECU enclosure.

6.4.1 Magnetic Pick-up Card(s) (MPU)

A speed sensor card(s) shall be provided. The MPU card shall contain circuitry for four speed sensor inputs (minimum). The inputs shall have a 5 ms update rate, on-board processor for automatic calibration of the I/O channels and low setpoint and high setpoint time stamping, to 5 ms resolution. The minimum specifications are as follows:

- a) Number Channels: 4
- b) Input Type: MPU (Magnetic Pick Up)
- c) Input Frequency Range: 50 Hz to 25 KHz
- d) Input Amplitude: 1 Vrms min, 25 Vrms max, Freq greater than 20 Hz
- e) Input Impedance: 2000 Ω
- f) Isolation Voltage: 500 Vrms
- g) Resolution: 16 bits 0.0015% of range per LSB
- h) Speed Accuracy (max): 0.01% over temperature range
- i) Temperature drift: 1 ppm/ $^{\circ}\text{C}$
- j) Derivative Accuracy (max): 0.10% of range (p-p)
- k) Speed Filter: 5-10,000 ms (2 real poles)
- l) Derivative Filter: 5-10,000 ms (1 pole + speed filter)

- m) Acceleration Limit: 1-10,000 percent/second
- n) Operating Temperature: -15 to +55 °C

6.4.2 High Density Analog Input/Output Card(s)

An analog input/output card(s) shall be provided. A combination input/output analog I/O card(s) shall contain circuitry for both the 24 channels of the 4-20 mA analog inputs and the 8 channels of the 4-20 mA analog outputs. The inputs shall have a 5 ms update rate, on-board processor for automatic calibration of the I/O channels, time stamping of two low setpoints and two high setpoints, to 5 ms resolution and 16 bit resolution. The minimum specifications for the analog inputs are as follow:

- a) Update time 5 ms
- b) Input range 0-25 mA or 0-5 Vdc; software and hardware selectable
- c) Isolation: 0 VRMS, 60 dB CMMR, 200 Vdc common mode rejection voltage;
no galvanic isolation
- d) Input impedance 200 ohms
- e) Anti-aliasing filter 2 poles at 10 ms
- f) Resolution 16 bits
- g) Accuracy: Software calibrated to 0.1%, over 0-25 mA full scale
- h) Temp drift 275 ppm/C, maximum
- i) Fuse: 100 mA fuse per channel
- j) Time stamping: 5 ms resolution on low event and latch, and high event and latch

The minimum specifications for the analog outputs are as follow:

- a) Update time: 5 ms
- b) Output Driver: Pulse Width Modulated (PWM)
- c) PWM frequency: 6.14 kHz
- d) Filter: 3 poles at 500 ms
- e) Current output: 4-20 mA
- f) Current output range: 0-25 mA
- g) Isolation: 0 Vrms
- h) Max load resistance: 600 ohms (load + wire resistance)
- i) Current readback: 8 bits
- j) Readback isolation: 60 dB CMRR, 200 Vdc common mode rejection voltage
- k) Resolution: 11bits
- l) Accuracy: Software calibrated to 0.2% of 0-25 mA full scale
- m) Temperature drift: 125 ppm/C, maximum
- n) Readback accuracy: 0.5% of 0-25 mA full scale
- o) Readback temp drift: 400 ppm/C, maximum



6.4.3 Discrete Input Card

A discrete input card(s) shall be provided. The discrete input card(s) shall contain circuitry for discrete inputs, which shall be optically isolated, and accessible through the discrete I/O FTMs specified in this document. The inputs shall have a 5 ms update rate, on-board processor for time stamping of the I/O channels with 1 ms resolution and galvanically isolated discrete inputs. The card(s) shall receive information from field switches and relays. Field wiring shall be isolated from the card(s) circuitry by optical isolators in each channel. The minimum specifications for the discrete inputs are as follow:

- a) Update time: 5 ms
- b) Input type: Optically isolated discrete input
- c) Input thresholds:
 - Low voltage: 8 Vdc at 1.5 mA = "OFF" greater than 16 Vdc at 3 mA = "ON"
- d) Input current: 4 mA @ 24 Vdc; 2.6 - 5 mA @ 125 Vdc
- e) External input voltage: 18-32 Vdc (UL)
- f) Isolation voltage: 500 Vdc to earth ground, 1000 Vdc to control common
- g) Time stamping: 1 ms resolution
- h) Isolated 24 Vdc contact supply: 400 mA maximum

6.4.4 Overspeed Monitoring Card(s)

An overspeed card(s) shall be provided. The overspeed card(s) shall be used to monitor two (minimum) independent frequency inputs and detect for a board-configured overspeed and input failed trips. This card shall be used in conjunction with a Dual Solenoid Monitor Card in order to output a command to the gas turbine fuel shutoff vales in the event of overspeed or channel fail condition. The Dual Solenoid Monitor Card is used to directly interface with the gas turbine fuel shutoff valve solenoids. The overspeed card shall have four indicators (minimum), one each for Input 1 Fail, Input 2 Fail, Overspeed No1 and Overspeed No 2.

6.4.5 Solenoid Monitor Card(s)

A solenoid monitor card(s) shall be provided. This card(s) shall be used to monitor and control two independent solenoid current inputs (minimum) for low or high current failed trips. The solenoid monitor card(s) shall be used to directly interface with the gas turbine fuel shutoff valve solenoids. The components for each channel shall be completely independent of each other, so that a component failure will only affect one channel. The card(s) shall have test features to allow each channel to be tested. There shall be six fault indicators (minimum), one each for an alarm and emergency stop and an undercurrent and overcurrent for each channel.



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6.4.6 RTD Input (100 ohm) Card

An RTD input card(s) shall be provided. The channels (eight minimum) of this card are to be semi-isolated. The channels shall be isolated from the control common but not from each other. The card(s) shall perform on-line temperature compensation and hardware diagnostics. The card(s) shall have no potentiometers and require no calibration. A card shall be capable of replacement with another card of the same part number without any adjustment. The minimum specifications for the RTD input card is as follows:

- a) Standard input: -40 to $+840$ °F (100 ohm platinum)
- b) Excitation: 2mA
- c) Module interface: VMEbus
- d) Output: Linearized temperatures in °F
- e) Resolution: 14 bit converter
- f) Accuracy: 0.5% of full scale over the entire temperature range
- g) Temperature Coefficient: 12 ppm/degree C
- h) Isolation: 1500 Vac continuous (input channels to control common, not channel to channel)
- i) Input Impedance: 2.2 M Ω
- j) CMRR: -90 db
- k) Status Indication: RED LED - channel fault or board fault

6.4.7 Discrete Output Card

A discrete output card(s) shall be provided. The discrete output (DO) card(s) shall individually control 32 outputs (minimum) according to commands from the CPU module. This card shall receive digital data from the CPU and generate non-isolated relay driver signals. The discrete output card(s) shall interface with relay FTM(s), each with 16 relays (minimum). The contacts of these relays shall connect to field wiring. A separate 24 Vdc power source must be provided for the relays. The minimum specifications for the discrete output card(s) are as follow:

- a) Update time: 5 ms
- b) Output Type: Open drain drivers, intended for use with relay interface modules.
- c) Fault Detection Readback: Output channel status
- d) System Faults: Outputs are turned off if communications with the CPU is lost.

6.4.8 Actuator Driver Card

An actuator driver card(s) shall be provided. Each channel (2 minimum) shall control an integrating hydro mechanical actuator and provisions for two-position feedback LVDTs. The actuator driver card(s) shall receive digital information from the CPU and generate proportional actuator-driver signals with a maximum range



of 0 to 25 mA dc. An on-board micro controller shall monitor the output voltage and current of each channel and alert the control system of any channel and load faults. The minimum specifications for the discrete output card are as follow:

- a) Number of Channels: 2 minimum
- b) Actuator Type: Proportional, hydro mechanical actuators
- c) Power requirements: +5V @ 0.5 A, +24 V @ 1 A
- d) Driver:
 - Current range: 25 mA Version ± 30 mA max
 - Dither Current: 25 Hz, 25% duty cycle, tunable amplitude
 - Max Load Resistance: $10/(\text{maximum current required, in amps})$
- e) Position Feedback:
 - Feedback devices: 2 per channel
 - Device types: LVDT
 - Excitation: 3 kHz sine wave, amplitude programmable from 2 to 8 Vrms, 120mA maximum, 1% THD maximum.
 - Input impedance of feedback circuit 200 k Ω
- f) Fault Detection:
 - Driver Alarm if current error greater than 10%
 - Alarm if open.
 - Alarm if shorted.
 - Excitation Alarm if voltage error greater than 10% or if in current limit.
 - Feedback Alarms for: open-wire, voltage-out-of range, computed position out-of-range; ranges programmable.
 - Position Error Programmable threshold and delay Microcontroller
 - Software watchdog is monitored by the CPU module. Hardware watchdog monitors logic power and microcontroller activity.
 - System Outputs turn off if communications with the CPU module are lost
- g) Performance:
 - Position Accuracy: 0.25% of full-scale @ 25 °C, does not include transducer error
 - Position Drift: 150 ppm/°C, does not include transducer drift
 - Output Current Tolerance: $\pm 1\%$ of full scale
 - Current Readback Tolerance: $\pm 5\%$ of full scale

6.4.9 Dataforth Analog Module

An analog input/output module that interfaces directly to FTMs that incorporate any combination of Dataforth input modules, up to 24 total inputs, and eight 4 to 20 mA analog outputs shall be provided.



6.4.10 Distributed I/O Module

Where applicable, a four channel distributed I/O controller module shall be provided that resides in the main electronic hardware chassis to act as a network master for each distributed I/O network channel. It must perform various scaling and linearization operations and control the flow of data between the system CPU module and the distributed I/O nodes. It must be able to determine the health of the nodes by comparing readback values to requested values on the output nodes, and check the reference test value on analog input nodes.

6.5 Field Termination Modules (FTM)

The contactor shall perform all internal interconnecting wiring. DIN-type field transition modules shall be mounted within the MPECU enclosure. These modules will serve as the physical interface between field I/O wiring, internal components and the VME I/O cards.

6.5.1 Analog Input/Output FTM(s)

The FTM(s) for analog input/output interface, process signals for direct output to the analog input/output cards. The FTM(s) shall be designed for mounting on DIN rails. A high-density analog/discrete cable(s) shall be used to connect the FTM(s) with the analog input/output card(s). There shall be +24 Vdc connections available for sourcing 4-20mA inputs. Each connection shall be protected with a 0.1 A fuse.

6.5.2 MPU/Dual Overspeed/Dual Solenoid/RTD Input FTM(s)

Analog input FTM(s) shall be used in conjunction with the digital speed sensor card(s) (MPU), dual overspeed card(s), dual solenoid monitor card(s) and the RTD input card(s).

A low-density analog cable(s) shall be used use to connect the FTM(s) with the appropriate card(s).

6.5.3 Discrete Input FTM(s)

A 24 Vdc Discrete Input/Output FTM(s) shall be used in conjunction with the discrete input card(s). The FTM(s) shall each have discrete input or output channel capability. The discrete input card(s) shall utilize the FTM(s) for its I/O connections. Low-density discrete cable(s) shall be used to connect the discrete input card(s) with the FTMs.

6.5.4 Discrete Output FTM(s)

This relay FTM(s) shall contain field-replaceable relays (DPDT). It shall be used to interface with the discrete output card(s). The relay FTM(s) shall connect to the discrete output card(s) via a low-density discrete cable(s). The relay FTM(s)



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shall be capable of being daisy-chained to another relay FTM(s) using another low-density discrete cable. The relay FTM(s) shall incorporate an I/O lockout relay that will de-energize all of the relays if de-activated by the I/O lock signal from the discrete output card.

6.5.5 Analog Output FTM

The FTMs shall interface signals from 16 channel, 12-Bit analog output cards to external equipment. Each FTM shall be designed for mounting on DIN rails. A multi-pin connector shall provide the interface to the analog output cards. The connections from the FTMs to the analog output cards shall be made by using a single standard ribbon cable. Sixteen (16) individual two-pin terminal blocks shall provide the signal interfaces for each channel to external equipment.

6.5.6 Dataforth compatible Input and Analog Output FTM

The FTMs shall be capable of mounting any combination of up to 12 Dataforth 4 to 20 mA, 0 to 5 Vdc, 100 Ohm or 200 Ohm RTDs and Type K thermocouple input modules along with 4 - 4 to 20 mA analog outputs. Each Dataforth module can plug into any of the 12 channels on the FTM. Each plug-in module converts the incoming signal to a 1 to 4 volt signal, which is sent to the Dataforth compatible 24 input / 8 output analog card. No calibration is required on the FTM or its plug-in modules. The plug-in modules are powered directly through the cable connector; resulting in no need for external power connections to the FTM.

6.5.7 Distributed Field I/O Modules/FTMs

Where applicable, the system shall be provided with DIN rail mounted distributed field I/O modules that are capable of being mounted remotely to the main control chassis. These distributed field I/O modules must communicate to the Distributed I/O module located in the main control chassis. Each distributed field I/O module shall contain multiple channels on each module that allows wiring from field devices to be connected directly to the distributed field I/O module. Various types of distributed field I/O modules must be provided. These distributed field I/O modules shall include the following types and configurations:

- 6 channel 200 Ohm RTD input module,
- 6 channel 100 Ohm RTD input module,
- 6 channel thermocouple (fail high) input module,
- 6 channel thermocouple (fail low) input module,
- 6 channel 4 to 20 mA without 24 Volt loop power input module,
- 6 channel 4 to 20 mA with 24 Volt loop power input module,
- 16 channel discrete 24 Vdc input module,
- 6 channel 4 to 20 mA output module, and



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8 channel discrete 5A output module.

6.6 Miscellaneous Internal MPECU Components

The Contractor shall, at a minimum, construct and deliver an MPECU in accordance with the equipment listed in this document. As final design warrants, additional equipment shall be at the discretion of the Contractor with final Government approval. All equipment shall be of high industrial quality.

6.6.1 Emergency Operating Panel (EOP) and Local HMI

A manual user interface panel shall provide an emergency stop pushbutton as well as a fire agent release inhibit switch, which will interrupt the command wiring to the primary and reserved release solenoids. The panel shall also provide a small audible alarm device, which is activated whenever a new unacknowledged alarm is generated on the HMI alarm screen. This panel shall be located in a conspicuous location at the front of the MPECU.

The front of the MPECU shall also incorporate a Human-Machine interface flat panel touchscreen. The graphical Human Machine interface shall be developed using Intellution's iFix software package and shall include graphical screens, which provide monitoring and control of all the functions described within this specification. The HMI package shall also include an alarm page, which displays all active alarms and provides the ability to acknowledge and reset the alarms. The front of the MPECU shall also include a local track ball and keyboard for operator interface to the HMI and associated troubleshooting and maintenance tools. The connections for trackball, keyboard, and monitor screen should be removable so that a KVM extension device can be installed within the MPECU cabinet to facilitate repeating the local HMI screen to a remote location. PS2 connections are preferred for the trackball and keyboard, and a standard 15-pin VGA connection for the display screen. The touchscreen portion of the display will not be repeated to the remote location. The government shall provide the KVM extension device and it is not the responsibility of the vendor under this specification.

6.6.2 Field Device Excitation Power Supplies

Two redundant, +24 VDC power supplies shall be mounted within the MPECU. The vendor shall determine the appropriate output amperage of the power supply.

6.6.3 MPECU Enclosure Over-Temperature Indication

A means of monitoring/indicating an internal over-temperature condition shall be provided, such as a miniature temperature switch/thermostat. This device shall



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provide an alarm displayed on the local HMI screen and shall automatically reset on return to normal conditions. The over-temperature monitoring device shall be rated in accordance with anticipated internal temperature conditions with over-temperature indication in the range of 125°F - 130°F.

6.6.4 MPECU Enclosure Temperature Transmitter

A means of monitoring/indicating internal temperature shall be provided, such as a miniature temperature transmitter. This device shall provide an analog output signal to an appropriate current signal conditioner card in the I/O section backplane and the value shall be displayed on the local HMI screen.

6.6.5 Vibration Monitoring Equipment

The MPECU shall include hardware capable of monitoring LM2500, LM2500+, and LM6000 vibration from either a velocity input or acceleration input, depending on the configuration of the turbine package under test.

7. Quality Assurance

7.1 General Requirements

7.1.1 Responsibility for Verification

Unless otherwise specified in the contract or purchase order, the Contractor is responsible for the performance of all verifications specified herein. The Government reserves the right to perform or witness any of the inspections or tests set forth in this document where such inspections or tests are deemed necessary to ensure equipment, data and services conform to specified requirements.

7.1.2 Test procedures

The Contractor shall prepare detailed test procedures for all tests specified herein. All test procedures shall be provided to the Government for review. Tests may be combined when this can be performed without one test obscuring the results of another test. These procedures shall contain a verification cross-reference index.

7.1.3 Test Conditions

Operational tests shall be conducted with the equipment operating under the following specified conditions, except for those tests where the following factors are variables:

- a. The ambient temperature shall be 73 deg F +/- 10 deg F.



- b. The ambient pressure shall be 27.5 +/- 3.5 inches of mercury abs.
- c. The relative humidity shall be 50 +/- 30 %.
- d. The supply voltage and frequency shall be 115 VAC and 60 Hz.

7.2 Verification Methods

All reports, test procedures and documentation associated with the verification methods shall be provided to the Government prior to equipment delivery.

7.2.1 Inspection

A pre-delivery inspection by the Contractor shall verify qualitative characteristics such as design and construction standards, quality of workmanship and physical features, and shall include the specific verifications listed below. The Government reserves the right to witness and participate in the pre-delivery inspection.

- a. Workmanship, assembly and fit.
- b. Parts, materials and finishes.
- c. Treatment for prevention of corrosion.
- d. Markings.
- e. Safety requirements.
- f. Cable harness dress.
- g. Dimensions.
- h. Weight.
- i. Point-to-point continuity check.

7.2.2 System Safety Analysis

A Contractor review of the design shall be performed on the MPECU to determine that the order of precedence to be used to satisfy requirements has been implemented in accordance with the requirements of paragraph 4.19.

7.3 Test Methods

7.3.1 Run-in

The MPECU shall be energized for a minimum run-in period of 12 hours, followed by a functional test. Run-in requirements shall apply only to electrical/electronic or electro-mechanical portions of components. Successful completion of run-in will be demonstrated by performance of the applicable test procedure.

7.3.1.1 Run-in Testing

Environment:	Specified in paragraph 7.1.3
Duration:	12 hours minimum, including test time.



Failure during test:

Two additional hours power-on followed by a functional test.

7.3.2 Documentation

Records and documentation shall be maintained to provide that all end item subsystems have completed the run-in period. Test Inspection Reports shall be initiated and processed on all functional features. All documentation shall be provided to the Government for review.

7.3.3 Government Product Acceptance

Following installation, each production unit will be energized by Government representatives and subjected to an operating test to ensure the following:

- a. Proper functioning of all I/O.
- b. Normal operation of all controls and switches, including all proper adjustments.
- c. If the run-in test is successful, it will be applied as the production acceptance test.

8. Responsibilities

8.1 Contractor Responsibilities

The Contractor, as the system designer, has responsibility for the equipment design, factory integration testing and ensuring the proper operation of the MPECU. Pursuant to this, the Contractor shall develop and provide to the Government, any and all plans, procedures, failure reports, and drawings (including internal MPECU wiring and interconnection drawings) necessary to appropriately document the supplied MPECU.

The Contractor shall provide periodic progress reports on the construction of the MPECU and drawing delivery status. This report should detail the progress of MPECU construction and testing, list all engineering drawings under development.

The Contractor shall support all purchased equipment and parts for a period of no less than seven (7) years. Material provided shall be commercially available off the shelf products from reputable contractors. This equipment will be available for procurement on a worldwide basis.

8.2 Government Responsibilities

Additional information, beyond that included in this document, will be furnished by the Government on an as needed and if available basis. The Contractor shall identify the need for additional information. Inability of the Government to make available the requested information shall not be cause for the Contractor to depart from the requirements of this document. The Government provides GFI in



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good faith; but if the Contractor finds any discrepancies with the GFI, it is the Contractor's responsibility to notify the Government immediately.

As previously stated, the Government shall assume final responsibility for design and construction of any required deck frame mounting assemblies. The Contractor shall submit mounting assembly designs/drawings to the Government.

9. Delivery

The MPECU shall be delivered to Naval Surface Warfare Center, Carderock Division Ship Systems Engineering Station (NSWCCD-SSES), 4850 South 15th Street, Bldg. 633, Philadelphia, PA. 19112. Delivery shall be no later than 6 months after contract award.